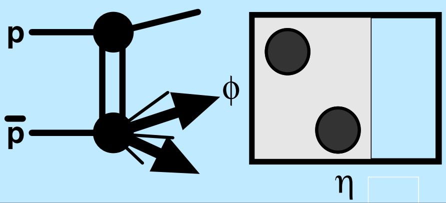
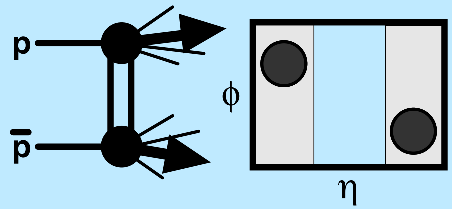
Diffraction at CDF

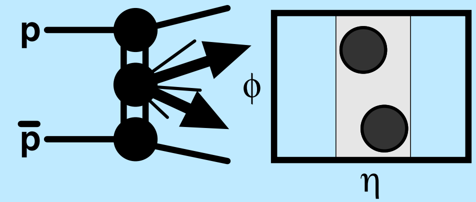
Christina Mesropian

The Rockefeller University

Diffraction at CDF in Run I







Soft Diffraction

Single Diffraction
PRD 50, 5355 (1994)

Double Diffraction
PRL 87, 141802 (2001)

Double Pomeron Exc.
Accepted by PRL

Multi-Gap Diffraction
PRL 91, 011802 (2003)

Hard Diffraction

Rapidity Gap Tag

W	PRL 78, 2698 (1997)
Dijets	PRL 79, 2636 (1997)
b-quark	PRL 84, 232 (2000)
J/Ψ	PRL 87, 241802 (2001)

Roman Pot Tag

Dijets:

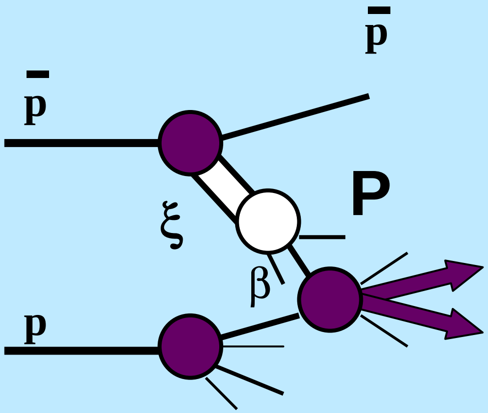
1.8 TeV	PRL 84, 5043 (2000)
630 GeV	PRL 88, 151802 (2002)

Jet-Gap_Jet

1.8 TeV	PRL 74, 855 (1995)
1.8 TeV	PRL 80, 1156 (1998)
630 GeV	PRL 81, 5278 (1998)

Dijets:
1.8 TeV PRL 85, 4217 (2000)

The Diffractive Structure Function



Subject of interest:
Hard diffraction process
production of high p_T dijets

Study the diffractive structure function

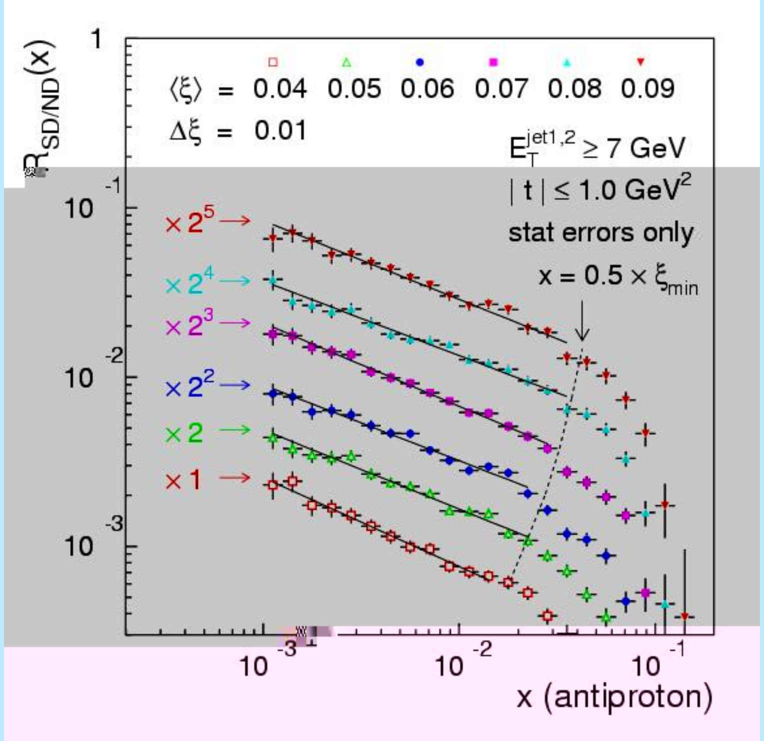
$$F_{jj}^{D}(x,Q^2,\xi)=g^{D}(x,Q^2,\xi)+\frac{4}{9}q^{D}(x,Q^2,\xi)$$

Measure ratio of SD to ND:

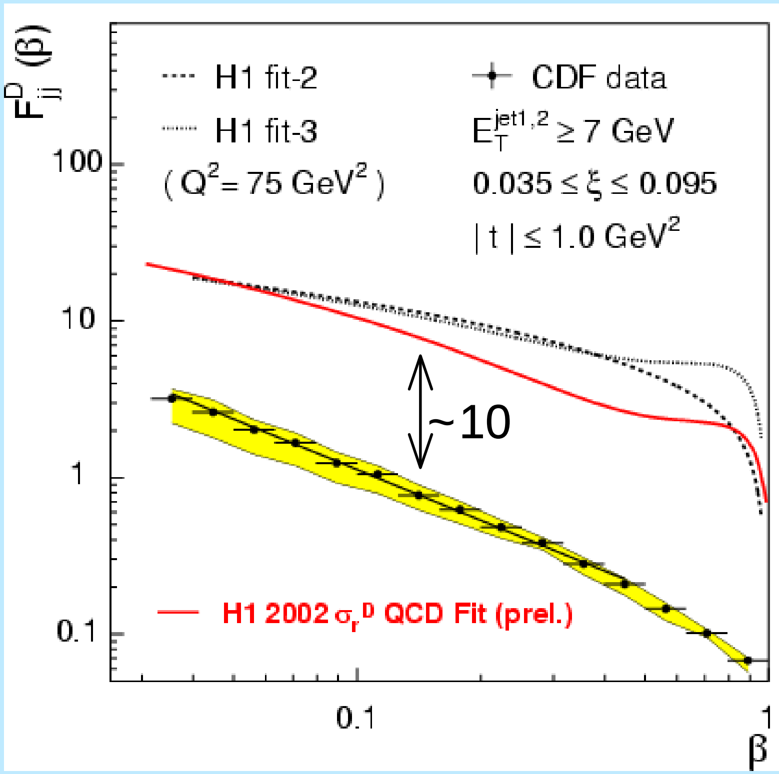
$$R_{\frac{SD}{ND}}(x_{\bar{p}},\xi)=\frac{\sigma(SD_{jj})}{\sigma(ND_{jj})}$$

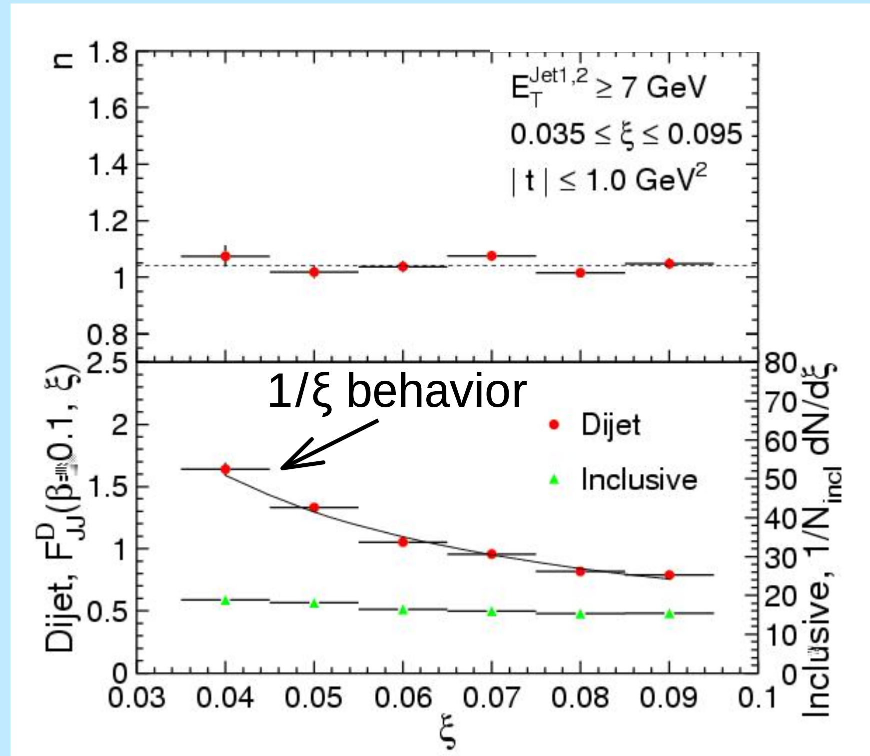
$$F_{jj}^{D}(x_{\bar{p}},Q^2,\xi)=R_{\frac{SD}{ND}}(x_{\bar{p}},\xi)\times F_{jj}(x_{\bar{p}},Q^2)$$

$$x=\beta\xi$$



The Diffractive Structure Function: Run I





discrepancy in normalization

⇩

QCD factorization breakdown

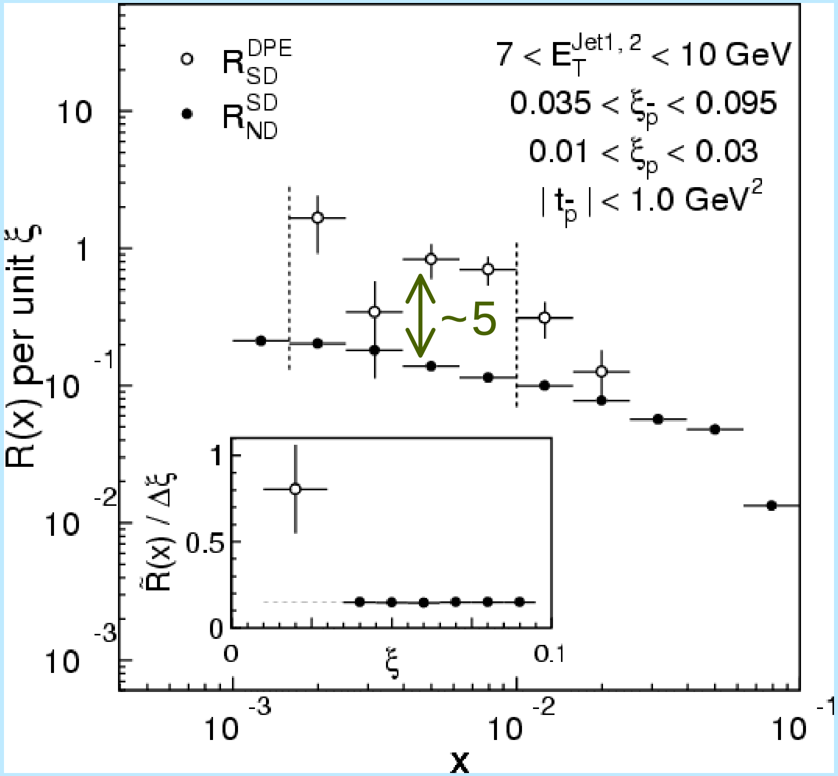
$$F_{jj}^{D} = C\beta^{-n}\xi^{-m}$$

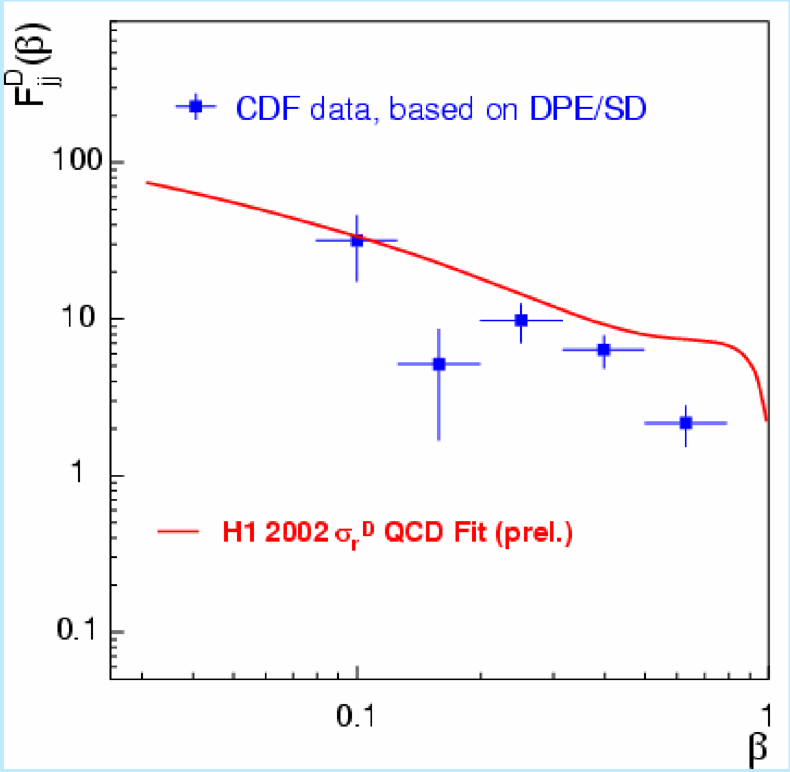
Regge factorization holds

$for\ \beta < 0.5$
$n = 1.0 \pm 0.1$
$m = 0.9 \pm 0.1$

Pomeron exchange

The Diffractive Structure Function using DPE dijets: Run I





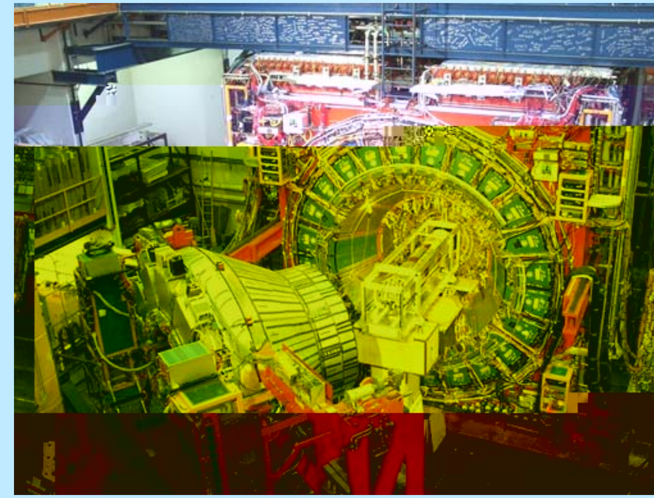
$$R_{ND}^{SD} / R_{SD}^{DPE} = 0.19 \pm 0.07$$

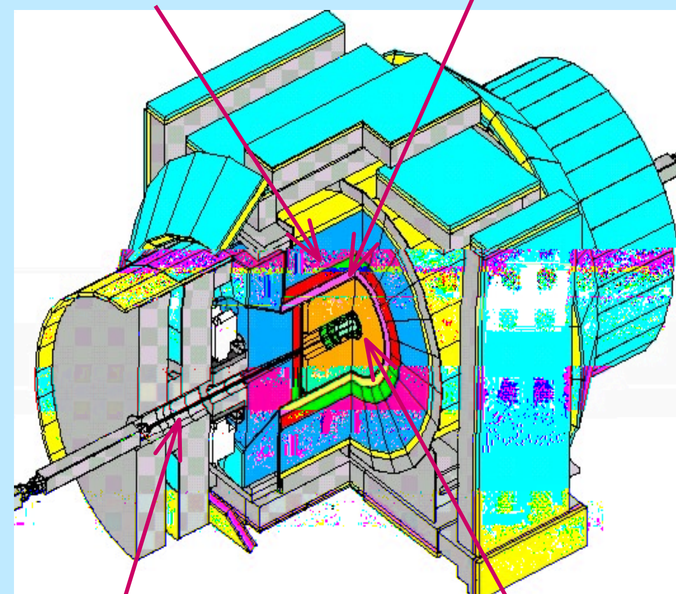
see prediction from
K. Goulianos hep-ph/0203141

$F_{jj}^{D}(\beta)$ measured using DPE dijets is ≈ to expectations from HERA

Factorization holds?

Run II





Tevatron:

$\sqrt{s}$ = 1.96 TeV

396 nsec bunch spacing 36x36

600 pb^{-1} of luminosity delivered as of August 2004

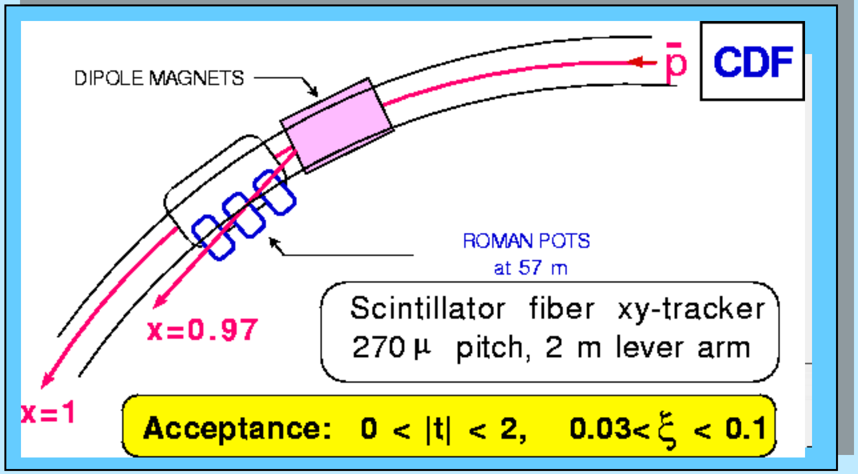
CDF:

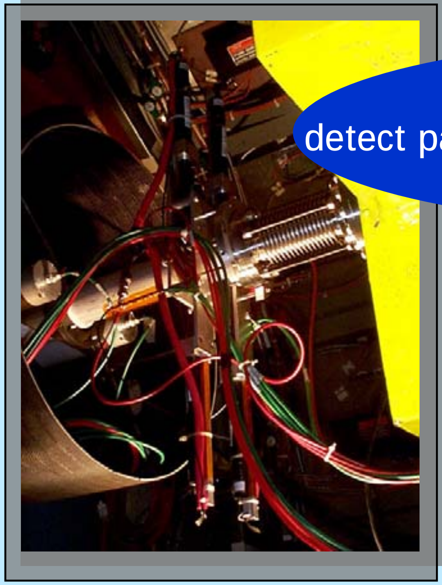
Data taking efficiency: ~ 80-90%

430 pb^{-1} of data on tape

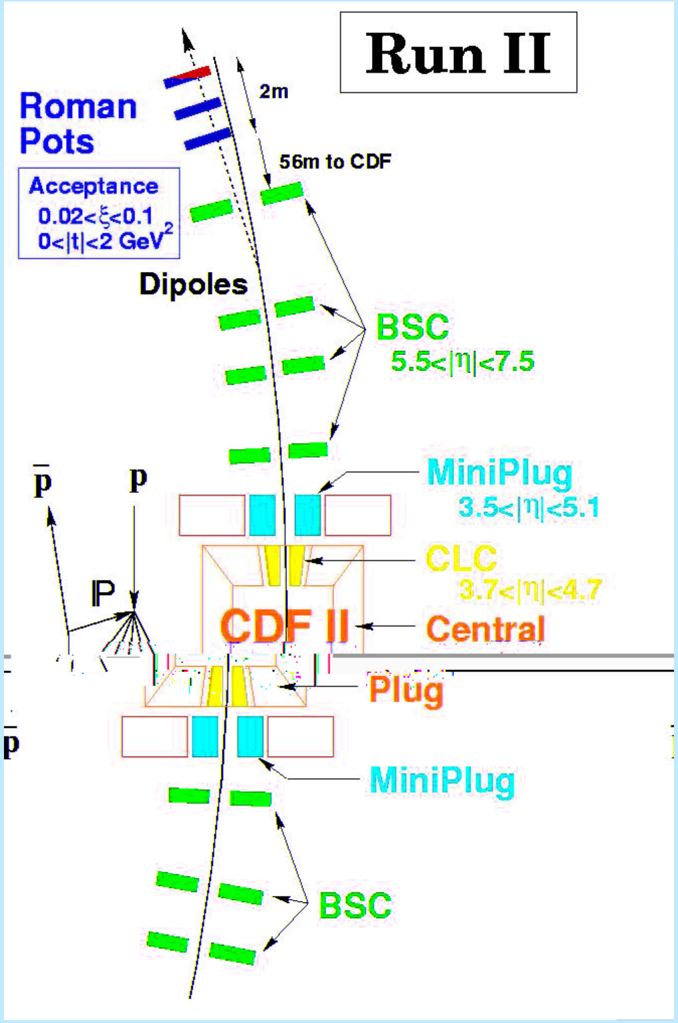
Forward detectors fully integrated

Run II: Forward Detectors

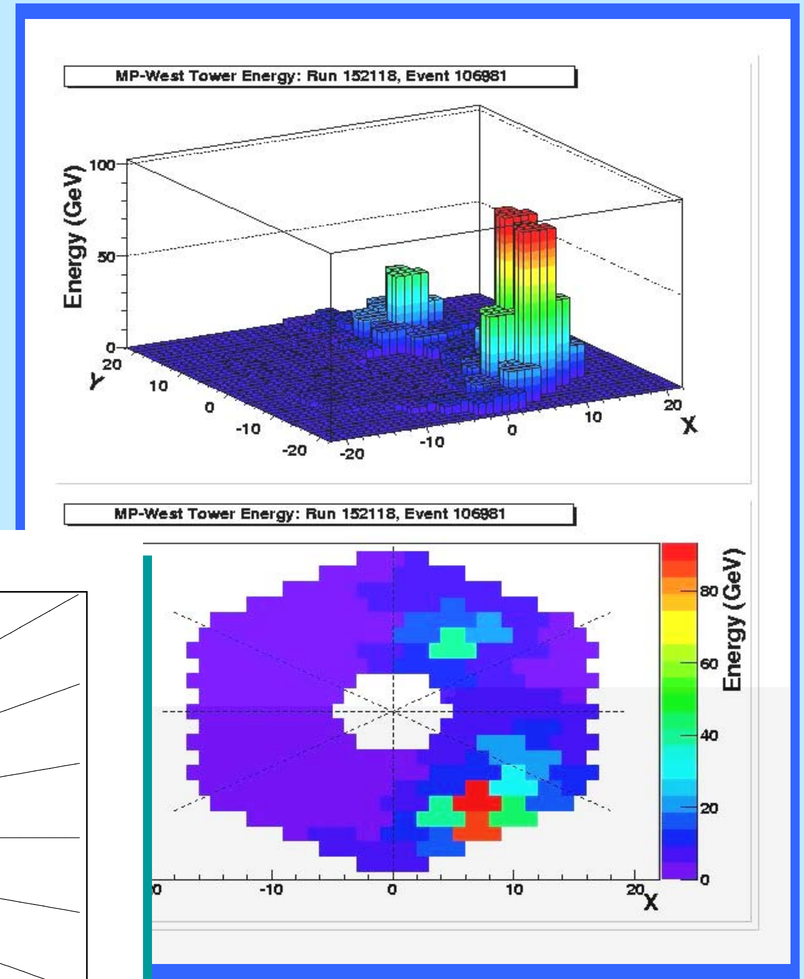


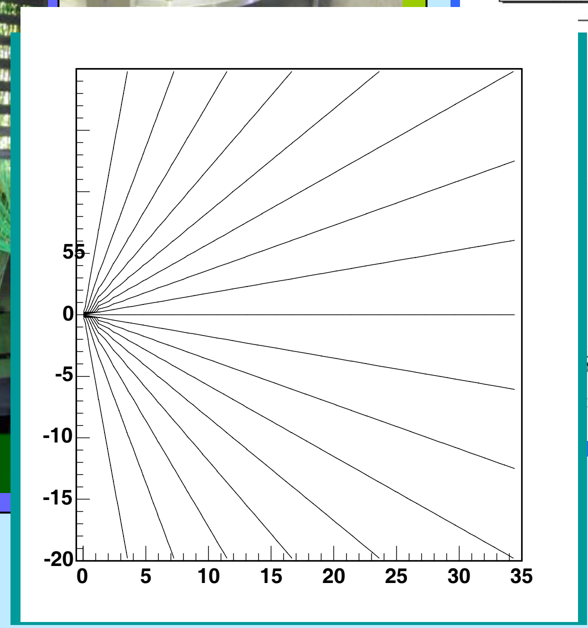


Scintillation counters:
detect particles traveling from IP along beam pipe
5.5 < |η| <7.5 coverage



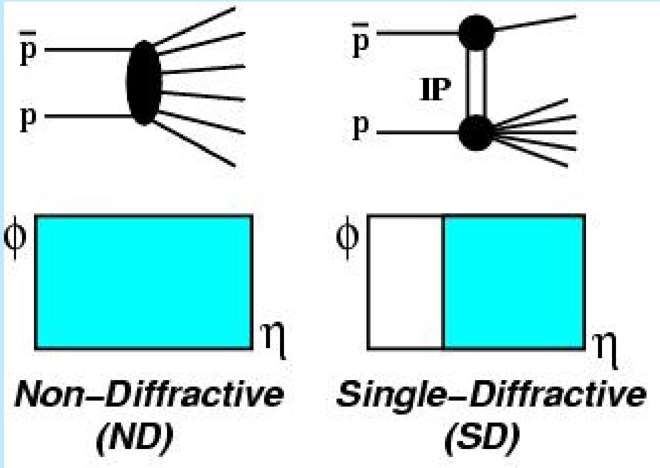
Run II: MiniPlug Design





Run II: Diffractive Dijets

Process

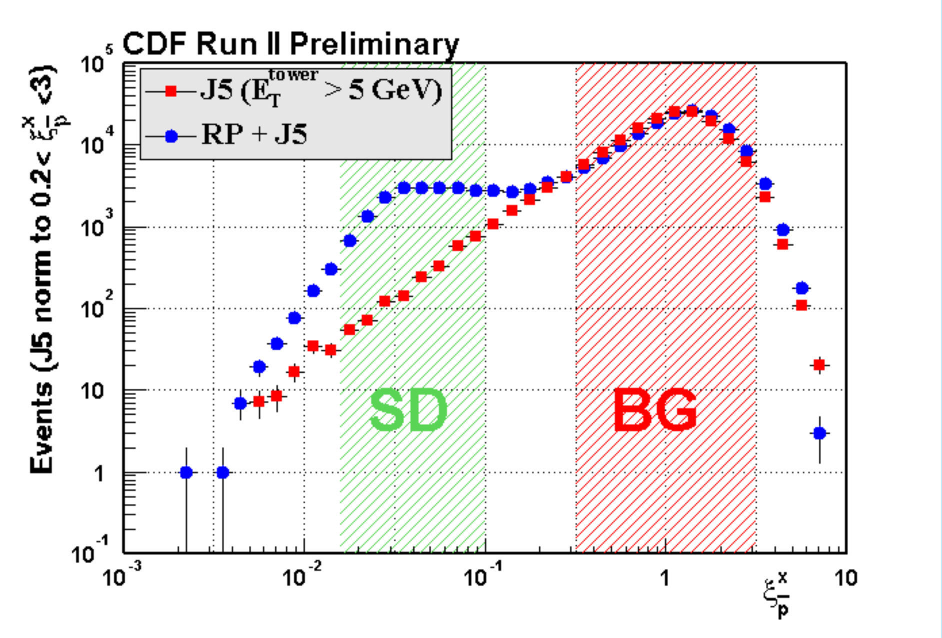


Method

measure ξ from calorimeter information
sum all towers except $\bar{p}$

$$\xi_{\bar{p}}^{X} = \frac{M_X^2}{s} \approx \frac{1}{\sqrt{s}} \sum_i E_T^i e^{-\eta^i}$$

MP energy scale: ±25% →Δlogξ = ±0.1
RP acceptance (0.03<ξ<0.1) ~ 80% (Run I)



Data:

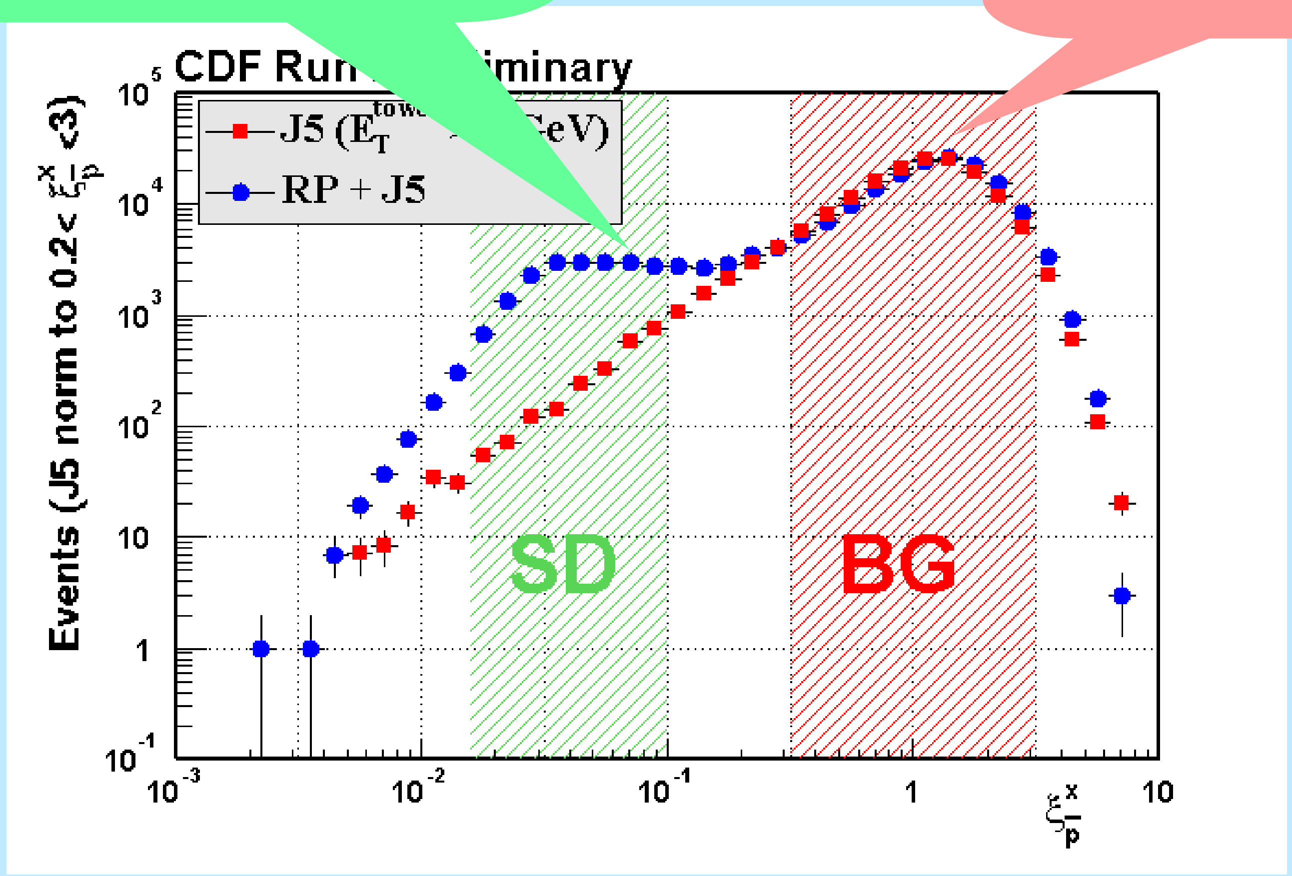
ND :	SD :
J5 trigger	RP+J5 trigger
≥1 cal. tower with E_T>5 GeV	leading $\bar{p}$ + ≥1 cal. tower with E_T>5 GeV

Run II: Diffractive Dijets

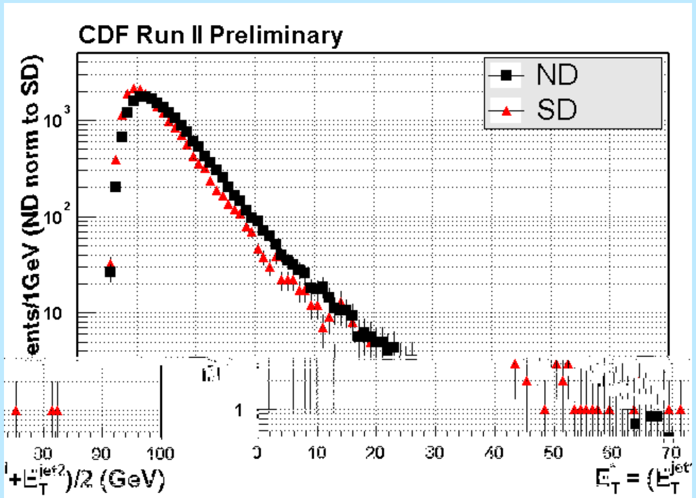
Flat part at ξ < 0.1

$$\frac{d\sigma}{d\xi} \propto \frac{1}{\xi} \rightarrow \frac{d\sigma}{d(\log \xi)} = const$$

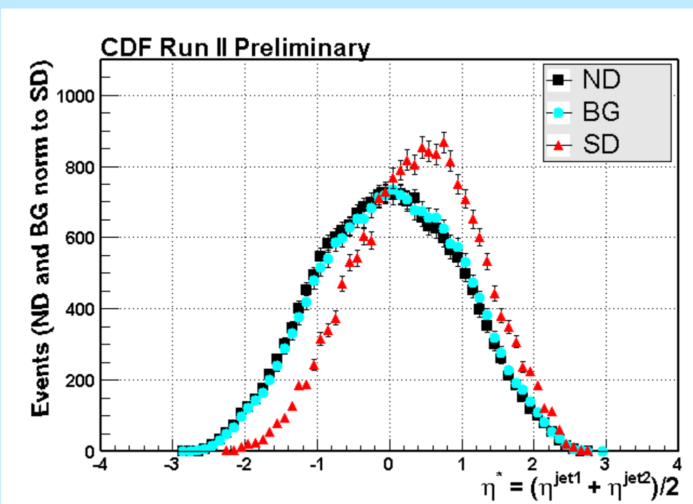
Peak at ξ= 1
-overlap events from
multiple interactions

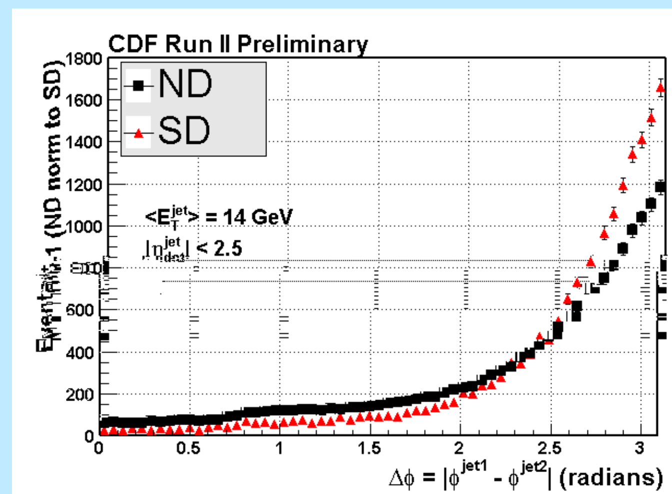


Run II: Diffractive Dijets

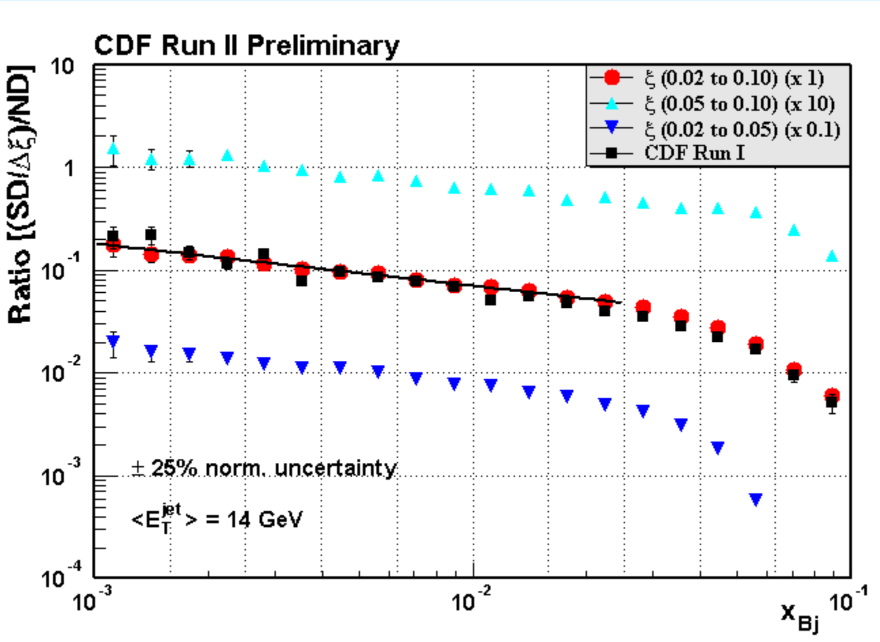


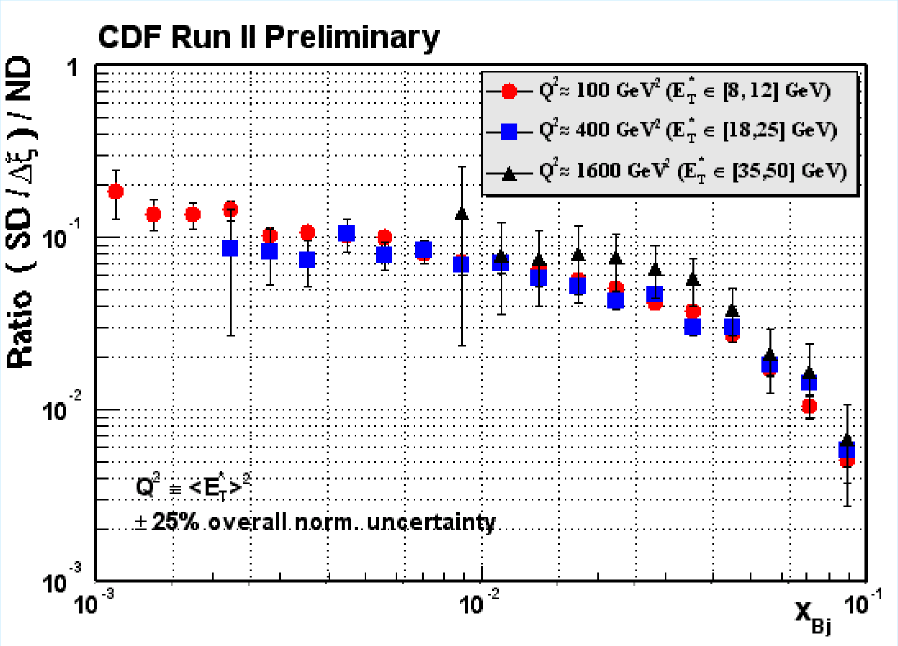
Distributions for SD and ND samples





Diffractive Structure Function





Ratio of SD to ND dijet event rates as a function of x_{BJ} compared with Run I

No ξ dependence is observed within 0.03<ξ< 0.1

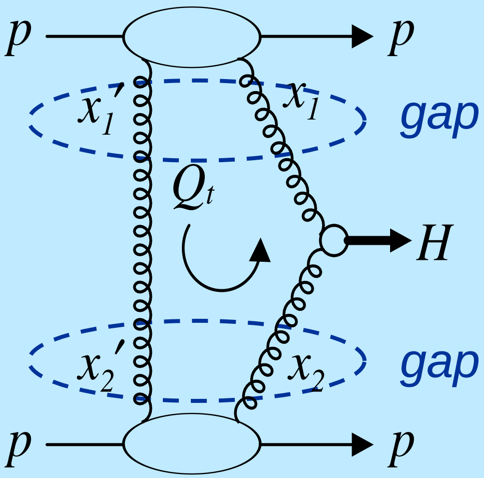
Confirms Run I result

Ratio of SD to ND dijet event rates as a function of x_{BJ} for different values of $Q^2 \equiv E_T^2$

No appreciable dependence is observed for 100< Q^2< 1600 GeV²

Pomeron evolves like proton?

Diffractive Higgs Production in DPE



Bialas and Landshoff
Khoze, Martin, Ryskin
Boonekamp, Peschanski, Royon

Attractive channel for Higgs discovery at LHC

Standard Model light Higgs:

$$p + p \rightarrow p + H(\rightarrow b\bar{b}) + p$$

"exclusive channel" →clean signal

$$M_H = M_{miss} = (s \cdot \xi_p \cdot \xi_{\bar{p}})^{1/2}$$

$\sigma_H^{excl} \sim 3\ fb,$

signal/background~3@LHC *(if* $\Delta M_{miss} = 1\,GeV$*)*

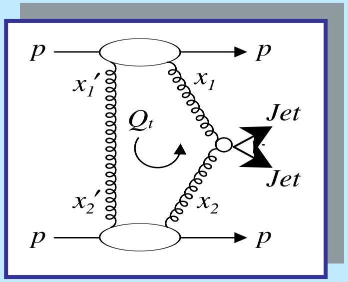
To calibrate Diffractive Higgs predictions

exclusive production in DPE

Exclusive **Dijets:**

$gg^{PP} \rightarrow gg$

large cross section

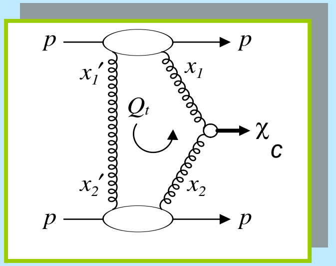


exclusive $gg^{PP} \rightarrow q\bar{q}$ suppressed

Exclusive χ_c^0 : $gg^{PP} \rightarrow \chi_c^0$

small cross section

clean signal



Exclusive Dijets in DPE: Run I

PRL 85, 4215 (2000)

132 inclusive DPE dijets:

events triggered by RP

kinematics: $0.035 < \xi < 0.095$

$2.4 < \eta_{gap} < 5.9$

$2\ jets,\ E_T > 7\ GeV$

Dijet mass fraction

$$R_{jj} = \frac{M_{jj}}{M_X},$$

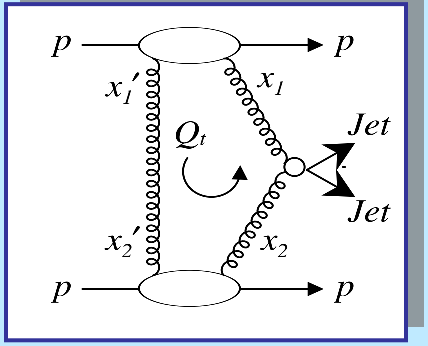
M_{jj} - invar. mass of 2 lead. jets

M_X - mass of the whole system, except p and $\bar{p}$

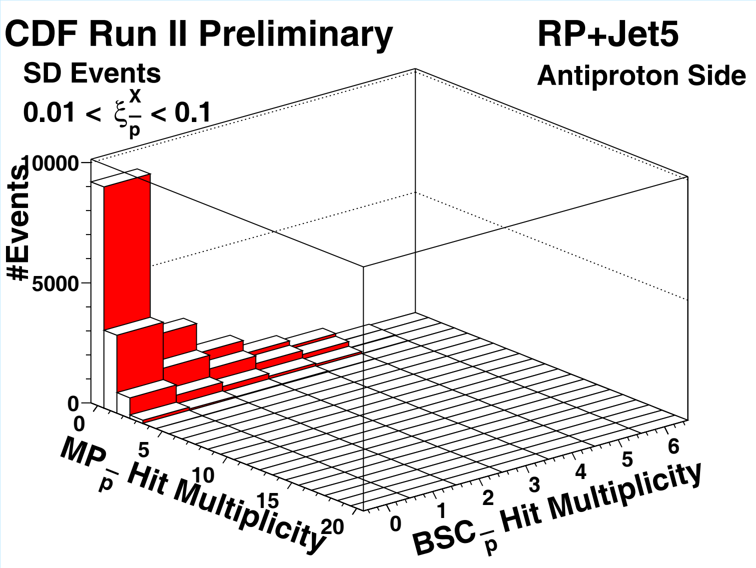
expected shape of exclusive dijets

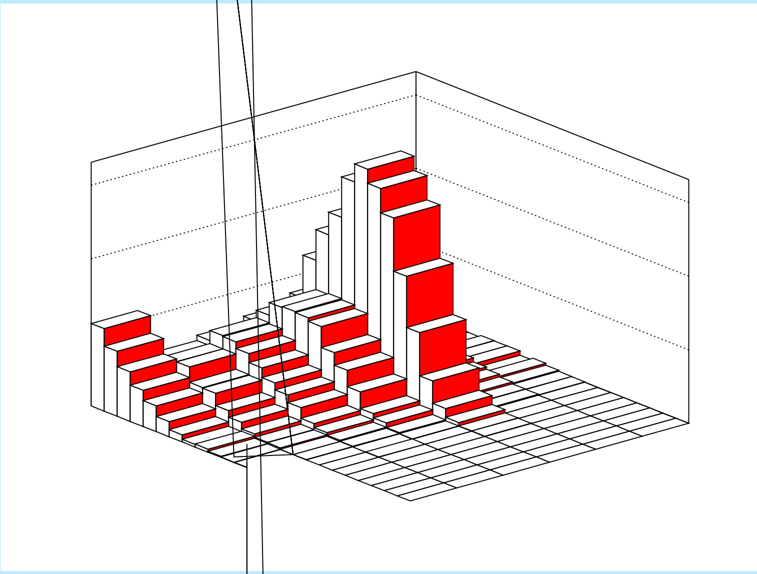
$$\sigma_{excl} < 3.7\ nb\ (95\%\ CL)$$

Khoze, Martin, Ryskin:
~ 1 nb (factor 2 uncertainty)
for Run I kinematics

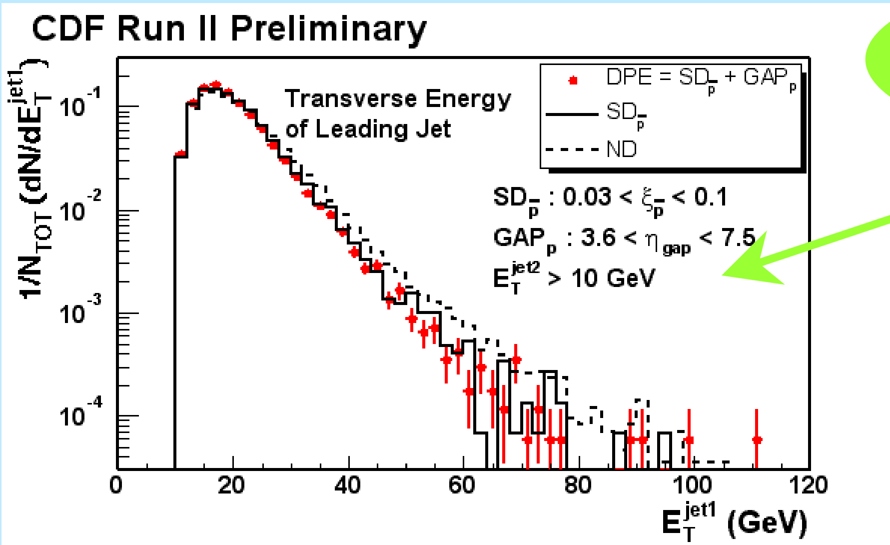


DPE Signal in SD Trigger Data





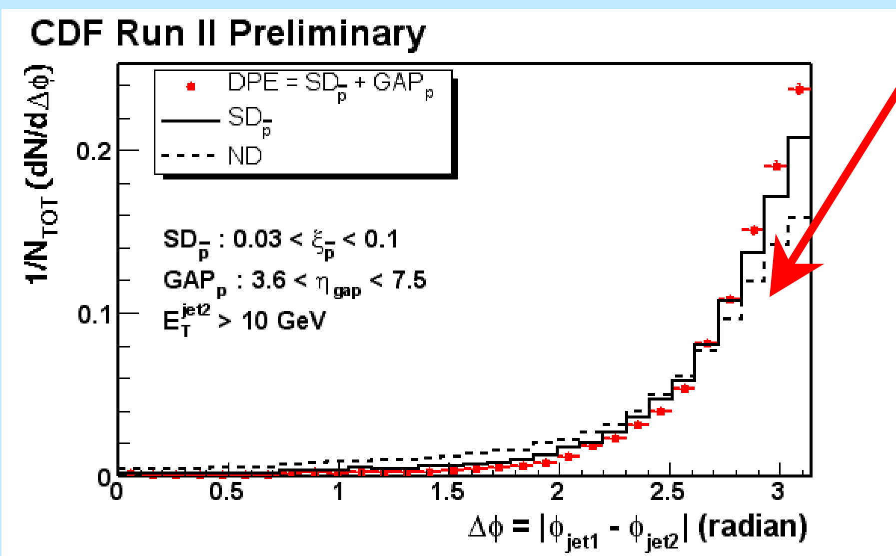
Kinematic Distributions

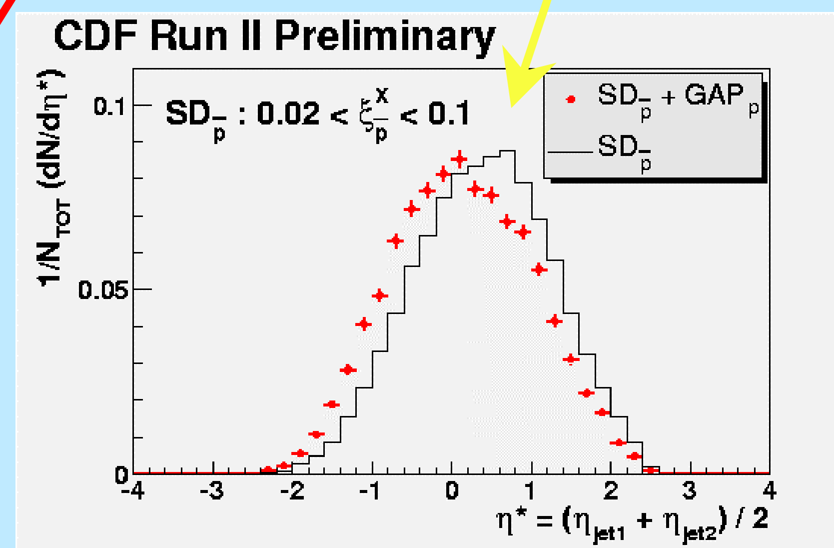


DPE jet E_T steeper than ND

$$\overline{\Delta\Phi}_{DPE} > \overline{\Delta\Phi}_{SD} > \overline{\Delta\Phi}_{ND}$$

SD jets boosted away from $\bar{p}$





Dijet Mass Fraction
Exclusive Dijet Cross Section Limit

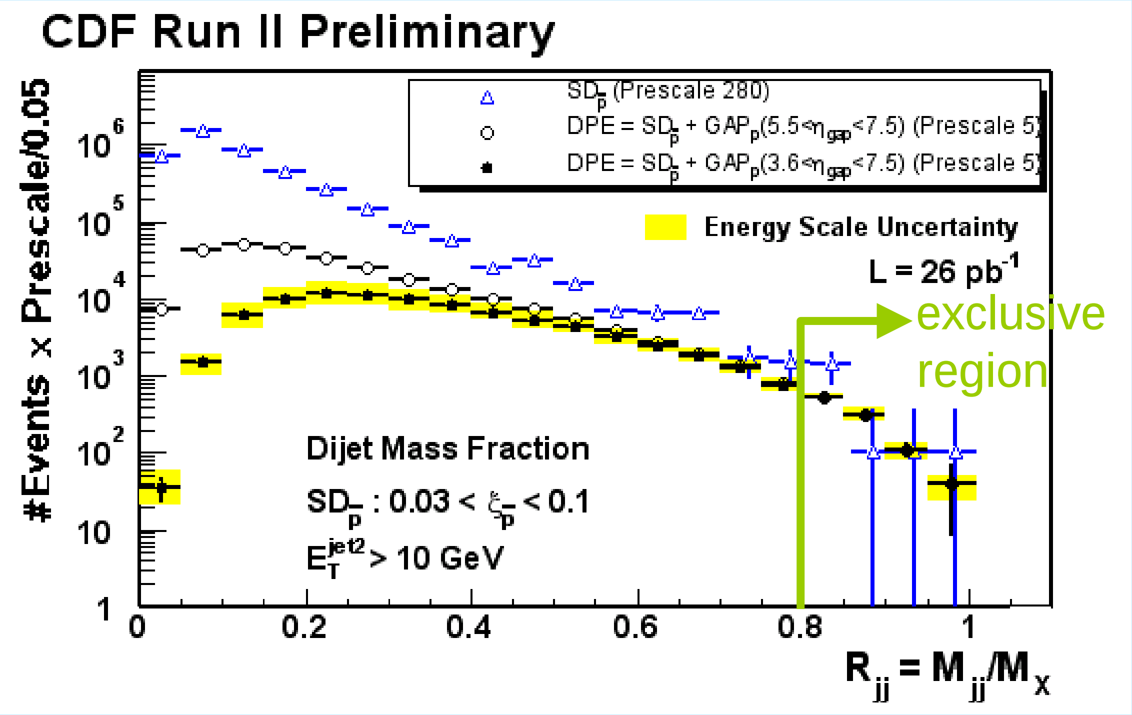
Triggered by RP+J5+BSC(E) gap

$$\left|\eta^{jet_{1,2}}\right| < 2.5$$

$$0.03 < \xi_{\bar{p}} < 0.1$$

$$3.6 < \eta_{gap} < 7.5$$

$$R_{cone} = 0.7$$



R_{jj} falls smoothly as $R_{jj} \to 1$

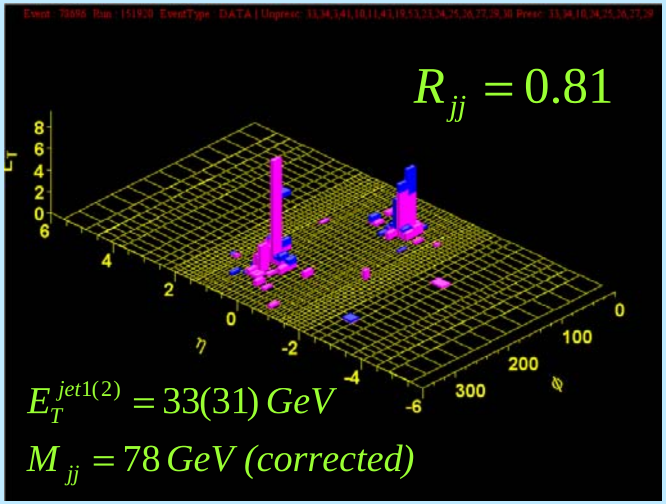
no significant excess at high R_{jj}

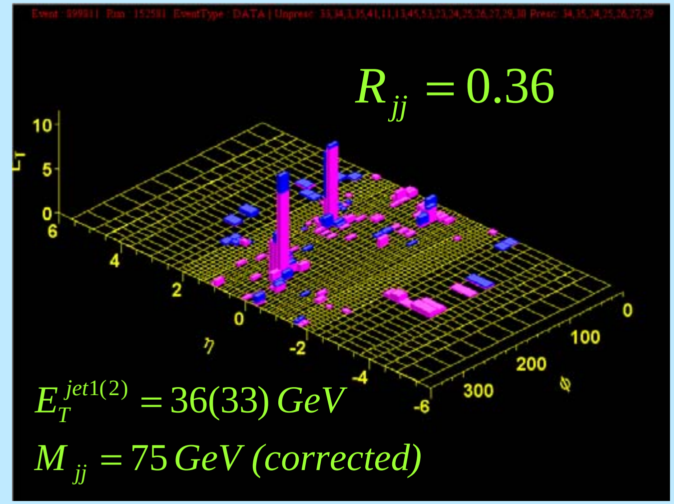
Khoze, Martin, Ryskin
Eur.Phys.J, C23,311 (2002)

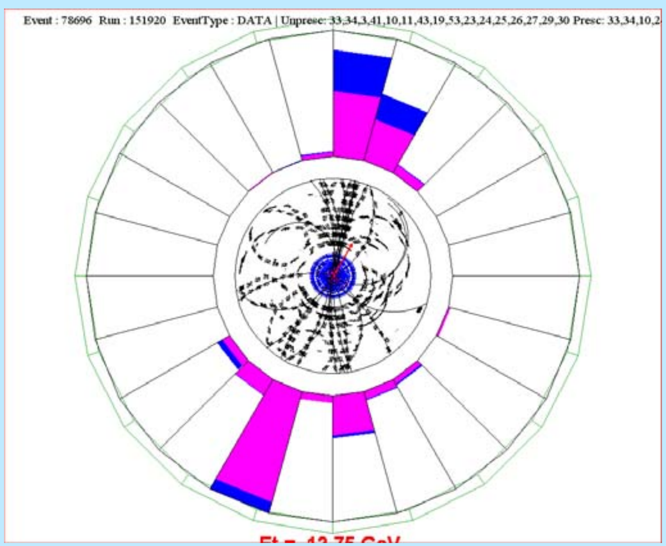
Theoretical predictions:
~60pb (factor of 2 uncertainty)

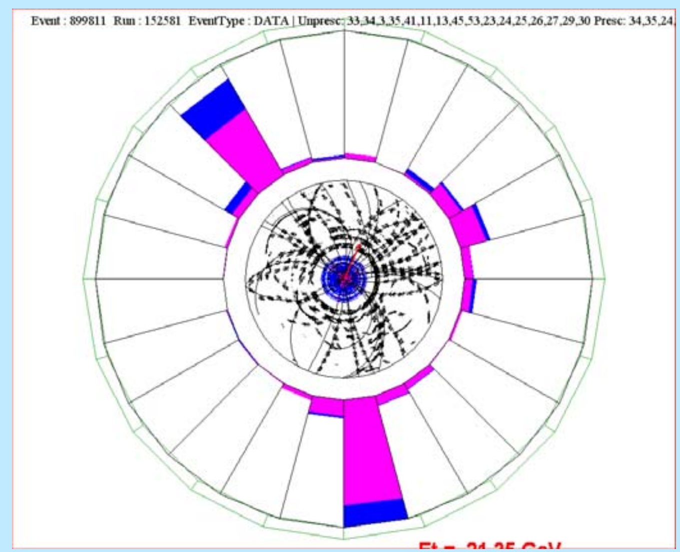
E_T^{jet1}	$\sigma_{DPE}(R_{jj} > 0.8)$
$> 10\ \mathrm{GeV}$	$970 \pm 65(stat) \pm 272(syst)\ pb$
$> 25\ \mathrm{GeV}$	$\mathbf{34 \pm 5(stat) \pm 10(syst)\ pb}$

Exclusive Dijet Events









Extracting Exclusive Dijets in DPE: Prospects

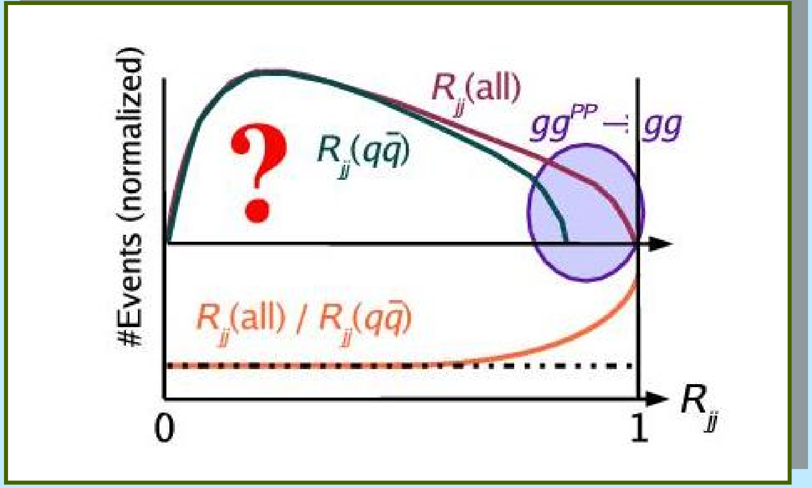
Experimental Method

normalize R_{jj} for all jets to R_{jj} for $Q\bar{Q}$ jets
look for excess as $R_{jj} \to 1$
pros: many exp. systematics canceled out
HF quarks identifies well:
g mistag @ O(1%)
cons: heavy quark mass
$\to$ contribution from exclusive b/c

Theory

$gg \to gg$ contribution is dominant in LO
$gg \to q\bar{q}$ is suppressed when $M_{jj} >> m_q$

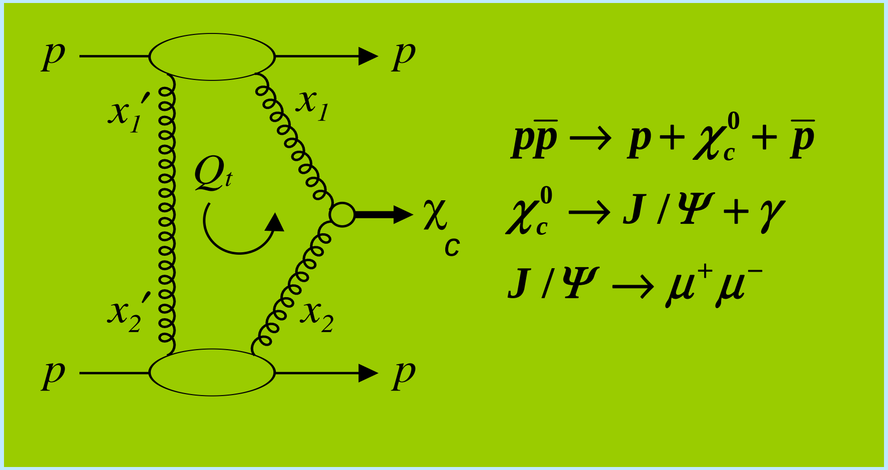
use $q\bar{q}$ suppression mechanism:
exclusive $gg \to gg$ might manifest itself as an excess over inclusive **qq** at high R_{jj}

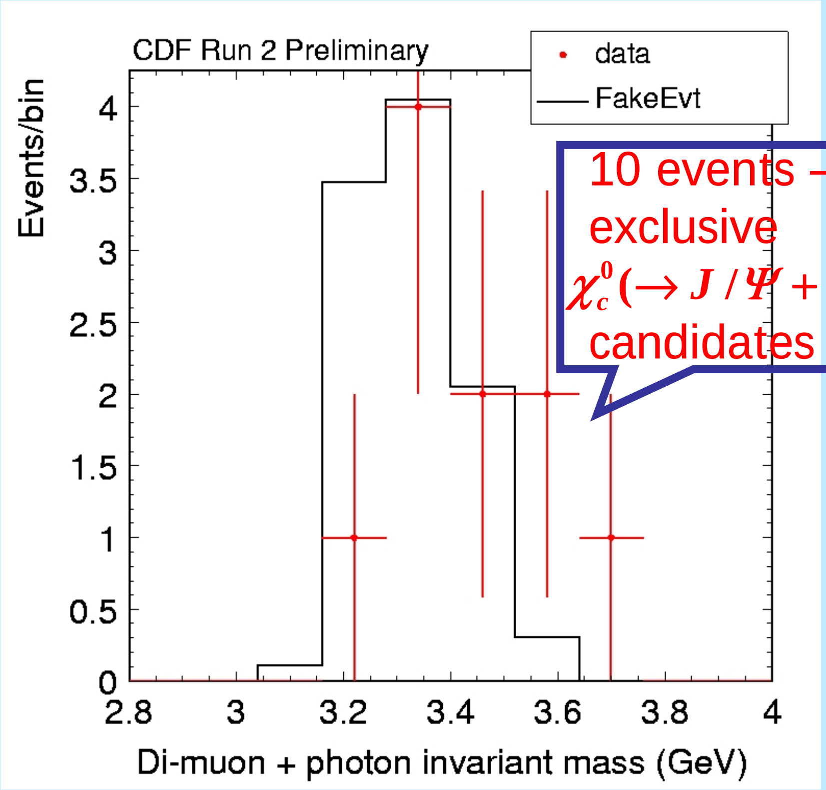


Supplemental analysis:
Difference of quark and gluon jets:

charged particle multiplicity in jet: N_{jet}
$N_{g-jet} \cong 1.6 N_{q-jet}$ (CDF Run I result)
study how N_{jet} behaves as $R_{jj} \to 1$
pros: sensitivity to light quark jets
cons: light q/g jets are not well separated

Exclusive χ_c^0 Production in DPE





Event Selection:

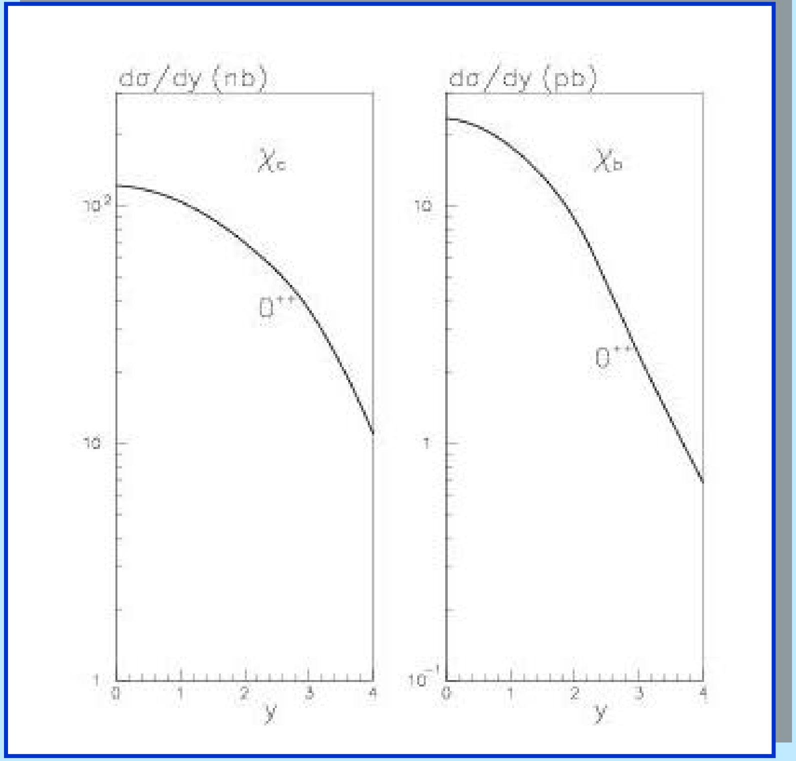
Di-muon trigger –
muon p_T>1.5 GeV ,|η|<0.6
Reject cosmic rays
with time of flight information
Select events in J/Ψ mass window
Require large gaps on both p and p sides

Data sample 93 pb^{-1}

BSC+MP gap	107 events
Calor.+CLC+trk+muon veto	23 events
EM tower	10 events

Exclusive χ_c^0 Cross Section Limit

Khoze, Martin, Ryskin
Eur. Phys. J. C19, 477 (2001)



Theoretical Predictions:

$$\sigma(p\bar{p} \rightarrow p + \chi_c^0 + \bar{p}) \approx 600\, nb$$

factor 2-5 uncertainty

$$\sigma(p\bar{p} \rightarrow p + \chi_c^0(\rightarrow J/\Psi + \gamma) + \bar{p})$$
$$\approx 70\ pb \text{ at } \left|y^{J/\Psi}\right| < 0.6$$

Assuming 10 events are all J/Ψ+γ

$$\left|y^{J/\Psi}\right| < 0.6,\ p_T^{J/\Psi} > 2\, GeV$$

"Upper Limit"

$$\sigma(p\bar{p} \rightarrow p + \chi_c^0(\rightarrow J/\Psi + \gamma) + \bar{p}) = 49 \pm 18(stat) \pm 39(syst)\ \text{pb}$$

Prospects:

Diffractive Structure Function studies:

Goals

- ❖ Measure Q^2 and ξ (at low ξ < 0.03) dependence of F_{jj}^{D}
- ❖ Study process dependence of F_{jj}^{D}

Q^2 Dependence: analysis in progress

RP+J5 data: $100<Q^2<1600$ GeV^2 range

RP+ higher jets even higher Q^2

ξ Dependence: analysis in progress

BSC(W)Gap+J5 goes below ξ =0.03

Process Dependence:

Measure F_{jj}^{D} from SD W (probing quark) and J/Ψ (probing gluon)

Prospects (continued):

Exclusive Final States studies:

Goals

- ❖Investigate existence/properties of exclusive final states
- ❖Derive the cross sections or limits

Exclusive Dijets: analysis in progress

extract exclusive dijets

quark/gluon composition as a function of R_{jj}

DPE b-jet trigger will be implemented after summer shutdown

Exclusive Low Mass States:

χ_c^0 - DPE-J/Ψ trigger - data being collected

$\gamma\gamma$ - DPE -γγ trigger in DAQ soon

Summary

Forward detectors are working well

- re-established Run I results using SD dijets
- no significant Q^2 dependence of F_{jj}^{D}
- Study of ξ and process dependence of F_{jj}^{D} in progress

- Improved upper limit on exclusive dijet production
- Obtained upper limit on exclusive χ_c^0 production
- DPE b-jet analysis in progress
- New DPE triggers

Many new exciting results are coming soon…